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ABSTRACT: Investigations to establish optimum conditions of heat treatment of semifinished sheet products from vanadium, tantalum and niobium obtained by electron beam melting were carried out. The interstitial impurity content has been tabulated and mechanical properties have been determined as a function of deformation and annealing temperature.

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Investigations were carried out in order to establish the optimum conditions /13* of heat treatment of semifinished sheet products from vanadium, tantalum and niobium obtained by electron beam melting. The content of interstitial impurities in the ingots is given in the table.

Metal	Impurity content % (in the bulk)				Hardness HB	
	O_2	N_2	H_2	C	Mn/m^2	kg/mm^2
Niobium	0.01	0.005	0.001	0.03	700	70
Tantalum	0.01	0.01	0.001	0.01	1100	110
Vanadium	0.06	0.005	0.001	0.015	1000	100

Sheet specimens 0.5 mm thick were prepared from the ingots by hot forging followed by hot and cold rolling.

The mechanical properties as a function of the degree of deformation and annealing temperature were determined on tensile-test specimens with a cross-section of 0.5 x 10 mm and a calculated length of 25 mm. The hardness was measured on a Vickers instrument under a load of 50 N (5 kg). The heat treatment was carried out in a vacuum resistance furnace at a residual pressure of 666.5 $\mu N/m^2$ (5×10^{-6} mm Hg). The metallographic investigations were carried out with an MIM-8 microscope at a magnification of 200-600.

Figure 1 shows curves characterizing the influence of plastic deformation on the mechanical properties of the metals studied. It is apparent from these data that as the degree of deformation increases, the hardness and strength increase, while the elongation per unit length decreases.

Studies of the microstructure of vanadium, niobium and tantalum as a function of the degree of deformation have shown that at 80% deformation and higher the metals acquire a fine fibrous structure. A marked change of the grain form is observed beginning at 20-40% deformation, this being associated with a decrease in elongation.

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*Numbers in the margin indicate pagination in the foreign text.

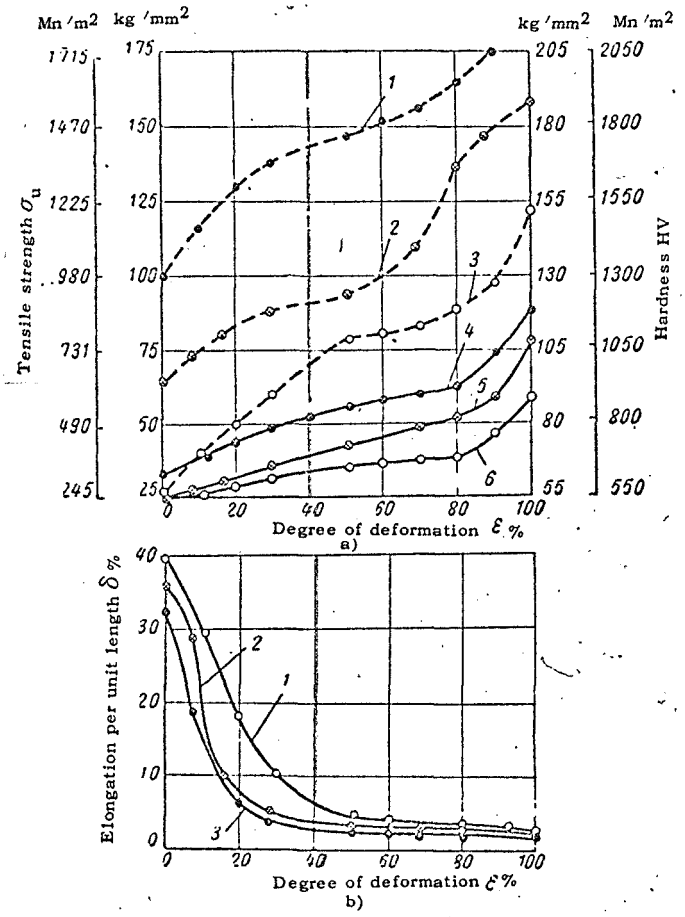

Figure 1. Change of Mechanical Properties of Vanadium, Niobium and Tantalum as a Function of the Degree of Deformation:

a—Tensile Strength of Tantalum (1), Vanadium (2), Niobium (3) and Hardness of Tantalum (4), Vanadium (5), Niobium (6); b—Elongation Per Unit Length of Niobium (1), Vanadium (2), Tantalum (3).

Under comparable conditions, the greatest hardness and strength are observed in tantalum and the lowest in niobium; vanadium occupies an intermediate position.

The curves of Fig. 2 show the change of hardness and strength of the metals with rising temperature. As is evident from these data, in the 200-600°C range the strength and hardness of niobium and tantalum increase slightly. At 1000-1200°C, the tensile strength and hardness of vanadium, niobium and tantalum decrease. A further temperature rise affects the change of strength. The elongation per unit length increases during annealing at 1000-1200°C. On annealing above these temperatures, a sharp decrease of the elongation of the metals studied is observed.

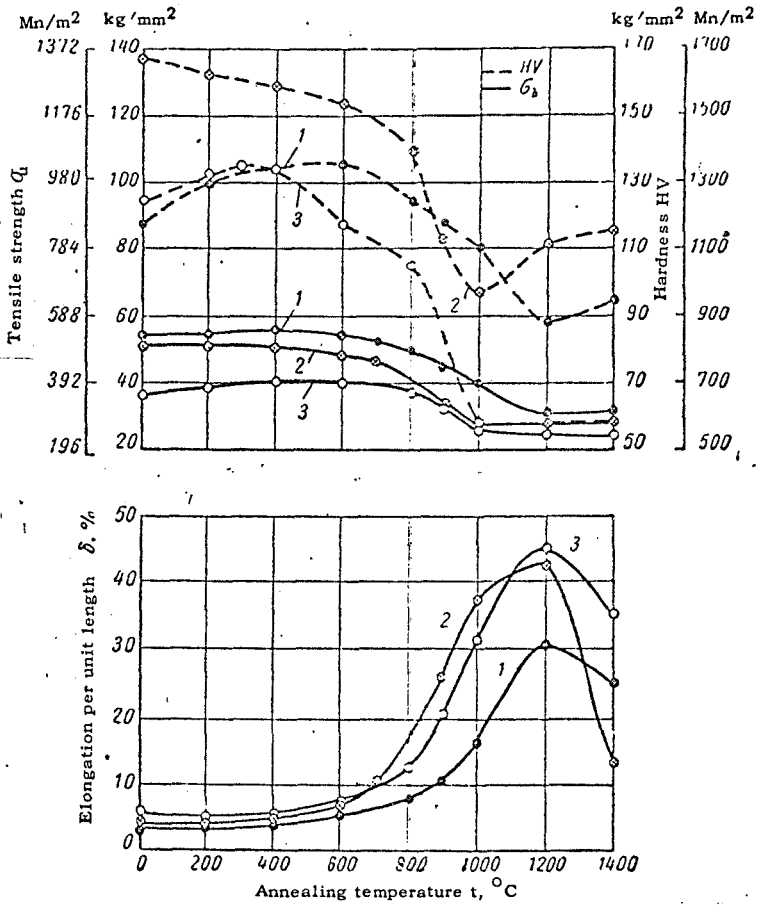

Figure 2. Change of the Mechanical Properties of Vanadium, Niobium and Tantalum as a Function of the Annealing Temperatures:

1) Tantalum; 2) Vanadium; 3) Niobium.

A disruption of the change of the strength characteristics of niobium and tantalum in the 200-600°C range of annealing temperatures is a consequence of strain aging. The fact of strain aging is confirmed by an increase of hardness after long-term holding of the specimens (at 400°C) in the recrystallized state. Aging was also noted during long-term holding of vanadium at 500°C. At the same time, the hardness of the specimens increases from 960 to 1100 Mn/m^2 (96-110 kg/mm^2).

The optimum temperature of the recrystallization annealing of vanadium, niobium and tantalum was chosen by considering the best combination of strength and plastic characteristics. Thus, at 80-90% deformation (the most typical degree of deformation for finished intermediate products), the recrystallization temperature of vanadium corresponds to 900-1000°C, niobium 950-1050°C, and tantalum 1100-1200°C. An increase in the degree of deformation shifts the recrystallization threshold into the

range of lower temperatures, and a decrease is accompanied by a rise of the recrystallization temperature. The influence of the degree of deformation and annealing temperature on the mechanical properties of vanadium is more fully represented in Fig. 3, from which it is apparent that the best combination of strength and plasticity characteristics corresponds to high annealing temperatures of vanadium. /16

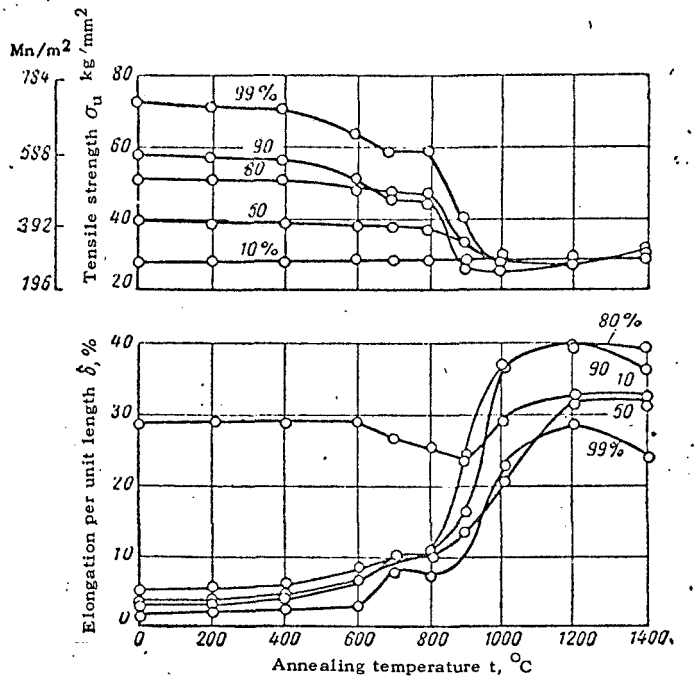

Figure 3. Tensile Strength and Elongation Per Unit Length Versus Annealing Temperature at Various Degrees of Deformation.

Similar dependences were obtained qualitatively for niobium and tantalum.

Data of the mechanical tests are in good agreement with the results of microstructural analysis. Figure 4 shows the microstructures of vanadium specimens annealed at various temperatures. The data cited indicate that an increase of the annealing temperature above the indicated recrystallization range is associated with a marked grain growth, which in turn causes a decrease of plasticity (see Fig. 2). For this reason, in order to obtain high-quality intermediate products from niobium, tantalum and vanadium, it is necessary to anneal them in a strictly defined temperature range.

The above investigations of mechanical properties as a function of the degree of deformation and annealing temperature and also data of microstructural and x-ray structural analyses made it possible to plot the temperature regions of recrystallization of vanadium, niobium and tantalum (Fig. 5).

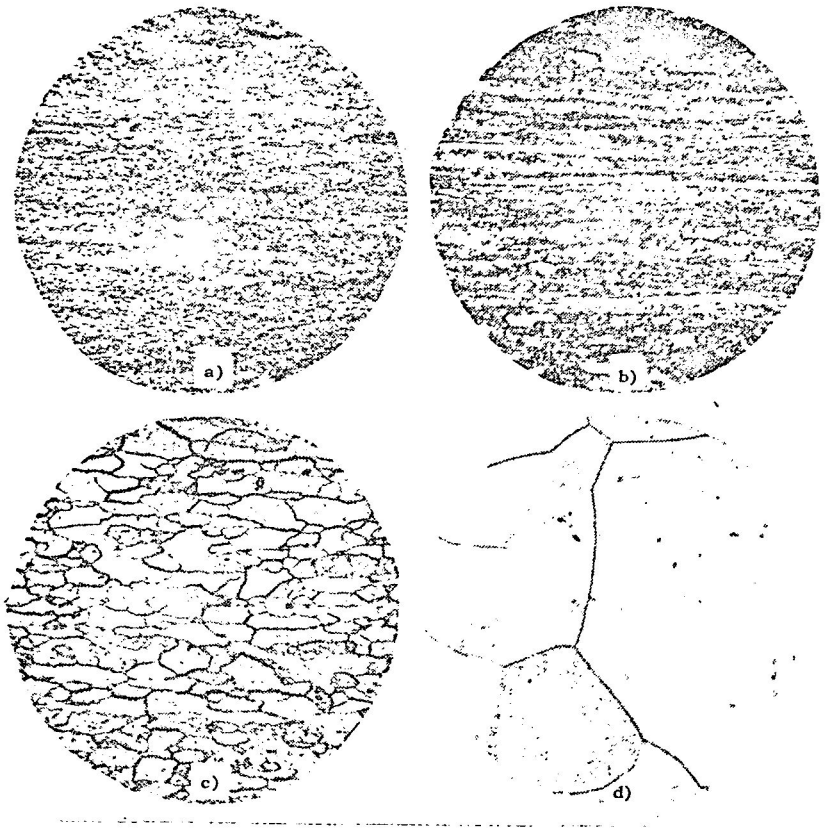

Figure 4. Microstructure of Vanadium Annealed at Various Temperatures (x 200)

a) Without Annealing; b) t = 900°C; c) t = 1000°C; d) t = = 1200°C.

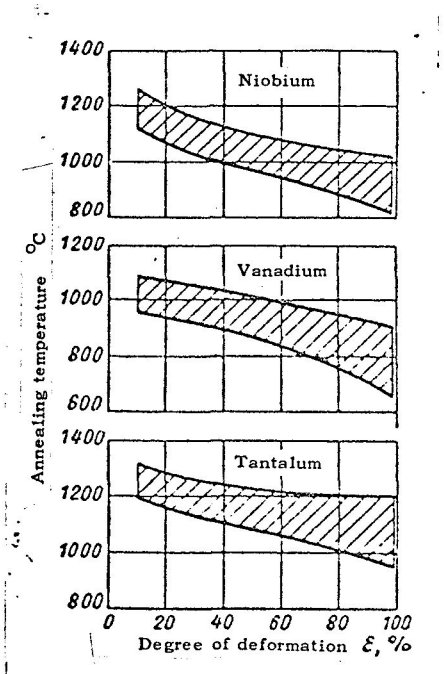

Figure 5. Temperature Regions of Recrystallization of Niobium, Vanadium, and Tantalum.

The data cited enable one to make the correct choice of the optimum conditions of heat treatment as a function of the degree of deformation of the products.

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